Eliminate or Reduce Opening Heat Losses

From Industrial Heating Equipment and Boilers

  

Prepared for California Energy Commission (CEC)

Prepared By:

Southern California Gas Company
(A Sempra Energy Utility)

E3M Inc.

May 2012

Disclaimer

Executive Summary

This calculator tool allows a user to estimate annual energy savings, reduction in CO_2 emissions, and the associated money (US dollars) savings when radiation heat loss from heating equipment (such as a furnace, an oven or a process heater) is minimized by reducing the size of openings or their time open. An opening can be in the form of a fixed opening such as a hole in the furnace wall or a stack opening. Variable opening heat losses are typically associated with a product charge or a discharge door that is kept open before, during or after the product is charged or discharged. Energy is lost primarily through thermal radiation from the opening.

This calculator allows the user to change the size of the opening or the time for which the opening (such as a charge or discharge door) is kept open. The calculator requires data such as the type of opening (rectangular vs. round), size of the opening (width and height or diameter) and the depth of the wall where the opening is located. The heat loss calculations account for the view factors associated with each opening and then allows calculations for the thermal radiation loss. Energy savings resulting from elimination or reduction of the opening size account increases the "available heat" for the heating system.

This calculator estimates the annual expected energy savings in terms of million British thermal units per year (MMBtu/year). It also estimates the energy cost reduction by using the given cost of fuel for the industrial application and the number of operating hours per year. This calculator also gives the reduction of CO_2 emissions that result from the combustion of natural gas.

The primary objective of this calculator is to identify energy savings potential in industrial heating operations to make a go / no go decision on further detailed engineering and economics analysis. The user is required to give data for several operating parameters that can be measured or estimated from normal operating conditions using available records. All data should be collected at average unit operating conditions.

Calculator results should be considered preliminary estimates of energy savings potential and a starting point for more detailed technical and economic analysis. Accuracy of the calculator's results is expected to be within plus or minus 5 percent.

Note to the user of this calculator tool

The following terms are used interchangeably used in this document. The terms furnace or heating system represent many different types of equipment used by the industry. They include furnaces, boilers, heaters, ovens, kilns etc.

Use of this tool requires knowledge of design, construction and operation of heating systems such as a furnace, oven, heater, boiler, kiln, dryer etc. The user is referred to several training programs and references quoted at the end of his document for further information on the available resources for getting trainings that would provide additional knowledge for the subject matters discussed in this document.   document.

TABLE OF CONTENTS

LIST OF EXHIBITS

1. Description of the subject area

This technical guide describes a calculator tool that enables a user to estimate annual energy savings and reduction in CO_2 emissions when radiation heat loss from heating equipment (such as a furnace, an oven, boiler, or other process heater) is eliminated or reduced by reducing openings, their size or time. Energy losses from opening occur primarily through thermal radiation. Heat losses can be reduced or eliminated by reducing the number of openings, size of the openings or by employing methods such as radiation shields. In some cases where the opening is variable (as in case of a door that is used for charging and discharging the load or charge material), it is possible to reduce the losses by shortening duration or time of the door opening.

An opening in envelope of a heating system could result in loss of energy in two ways:

1. Heat loss by thermal radiation. This loss depends on the size and shape of the opening, the temperature differential between the radiation source and the surroundings (such as interior of a furnace and the ambient temperature), depth of the opening (thickness of furnace wall), and emissivity of the furnace interior (in many cases, the emissivity is high and ranges between 0.7 to 0.95).
2. Heat loss due to air leakage into the furnace (negative furnace pressure air leakage in a furnace results in an increase in mass flow through the flue gases and an increase in oxygen (O_2) content within the flue gases. This results in an increased flue gas heat loss and a drop in unit efficiency.

The focus of this tool is on the reduction of natural gas requirements used for industrial processes by eliminating or reducing opening heat losses. There are three main measures to eliminate or reduce radiation heat losses:

- **Eliminate or plug the opening.** – This measure is used when the furnace walls contain openings, which are not used on a regular basis. Examples of such cases include openings for collecting product samples, visual inspections of the furnace interior, data collection etc.
- **Install devices such as curtains or radiation shields that will reduce the heat losses.** – This measure involves installing flexible curtains using appropriate material (ceramic cloth, metal chains etc.) to block and reduce radiation from high temperature of a furnace zone to the surroundings. These devices can be used where it is necessary to allow unrestricted access to the openings for product charging or discharging. Care should be taken in the design to avoid damage to the product, product surfaces or a risk of product being "hung-up" in the openings.
- **Reducing opening time for variable openings –** This measure involves minimizing charging and discharging times to reduce radiation losses and air leakage into the furnace.

A brief summary of the important parameters follows:

- **Size and shape (rectangular or round) of an opening –** For round openings the size is expressed in terms of diameter of the opening and length of the opening. For rectangular openings, the dimensions are expressed as length and height of the opening, and the depth of the opening. In many cases, the length (or depth) is equal to the furnace wall thickness at the opening. However in other cases it can be length of a stack or height of a container etc.

- **Furnace Temperature** – This represents temperature of radiation source, which is often the interior temperature of a furnace.
- **View factor** – This is a factor that accounts for fraction or percentage (%) of the radiation heat loss if the opening dimensions were very large compared to the furnace wall thickness.
- **Emissivity** – The emissivity (expressed as % of blackbody emissivity that is 1.0) of the radiation source. In most cases for openings in a furnace, this number would be close to 0.9 to 0.95.
- **Flue Gas Temperature** – The temperature of the flue (stack) gases exiting the process before and after implementation of the efficiency measure.
- **Oxygen Concentration in Flue Gas** – The percentage of oxygen in the flue gas measured on a dry basis before and after implementation of the energy saving measures.
- **Combustion Air Temperature** – The temperature of the combustion air (which is the air mixed with fuel in the burner) before and after implementation of the efficiency measure.
- **Fuel consumption per hour (MM Btu/hour)** – The average estimated hourly consumption of natural gas (or other type of fuel) by the baseline combustion system (furnace, oven, kiln, etc.). This should be based on a recent 12-month period (MM Btu/year) and number of hours for the heating system.
- **Number of operating hours (hours/year)** – The number of hours for which the equipment is operated. This should be based on a recent 12-month period.
- **Cost of fuel -** The average fuel cost ($/MM Btu) based on the past history and, if possible, future projected cost based on contacts with the energy supplier.

2. Impact of opening loss on energy savings, CO_2 emissions, and water savings

This calculator allows a user to estimate energy (fuel) savings that can be achieved by eliminating or reducing heat loss through openings in a furnace. These fuel savings result in a reduction of CO_2 emissions. All commonly used fossil fuels such as natural gas, the most commonly used industrial fuel for California industries, results in the formation of CO_2. The reduction in CO_2 emissions is directly proportional to the reduction in natural gas use.

The CO_2 savings are directly related to energy savings. According to U.S. Environmental Protection Agency (EPA) estimates (Reference 5), the combustion of natural gas used in USA produces 116.39 lbs. of CO_2 per MM Btu heat input. For convenience, most calculations use 117 lbs. CO_2 emission per MM Btu heat input from natural gas. If the natural gas composition is available, it is advisable to carry out detailed combustion calculations to estimate values that are more accurate for the CO_2 produced by the combustion of natural gas. Reduction in CO_2 emissions is calculated by using the value of reduction in energy (fuel) used for the furnace.

The actual savings in fuel consumption and the associated energy costs depend on several design and operating parameters. These include:

- Size, shape and number of openings for a furnace.
- Furnace temperature in the area of openings.
- Ambient temperature near the openings.
- Temperature of exhaust gases leaving a furnace or boiler
- Amount of excess air used for combustion as represented by presence of oxygen (dry basis) in the exhaust gases.
- Number of operating hours per year
- Average temperature of the combustion and excess air entering the heating system.
- Cost of fuel in terms of $/MMBtu

The energy savings can vary from 1% for low-temperature processes to as high as 10% for high-temperature processes. The exact value of savings can be estimated by using this calculator.

Heat required to compensate opening heat loss has to be supplied from the available heat in a furnace. The available heat represents heat remaining in a furnace that is the heat supplied by the burners minus heat lost in flue gases.

Hence, the actual heat input reduction for a furnace could be considerably higher than the heat loss reduction calculated by using this tool.

Annual energy cost savings depend on the cost of energy, expressed as US dollars per MM Btu, and the energy savings estimated using the calculator.

3. Discussion on the technical approach and the calculations

Reducing the opening heat losses will result in energy savings while maintaining the desired heat output or furnace temperature. The annual energy savings (MM Btu/year) is the difference between the annual energy use by the baseline system and the annual energy use by the heating system after the implementation of this efficiency improvement measure. In all cases involving opening heat loss reduction, an essential step is to make the following measurements.

- The furnace interior temperature
- Dimensions of the openings and furnace wall thickness or depth of the opening
- A flue gas analysis with measurements of the flue gas temperature and oxygen concentration with a flue gas analyzer. The percentage of oxygen in the flue gas can be

measured by inexpensive gas-absorbing test kits. More expensive ($500-$1,000) hand-held, computer-based analyzers display percent oxygen and flue gas temperature. In addition, the combustion air temperature is required.

A schematic of a heating system considered in the opening heat loss calculation is illustrated in Exhibit 1 below. The flue gas mass flow includes the combustion air entering through the burner, make up air (if used) and air leaks into the system. The flue gas (including combustion products and excess air not used for combustion) exits the heating system chamber through the stack.

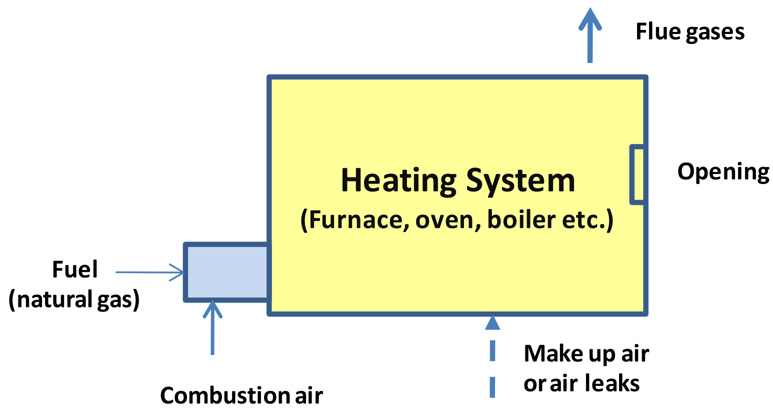

Exhibit 1: Heating system schematic with openings.

The opening loss is primarily loss of heat by radiation. Basic equation for thermal radiation is given below.

Where

Q Rate of heat transfer, Btu/hour

ε Emissivity of the source surface

F_a A factor related to arrangement (line of sight) of the two surfaces

T_{source} Absolute (°F + 460) temperature of the radiation source

T_{sink} Absolute (°F+ 460) temperature of the receiving surface

A Opening or Surface area, sq. ft.

For most commonly encountered cases, the emissivity can be assumed to be 0.9.

The factor F_a is often known as view factor that depends on geometrical arrangement of surfaces (or "available view") of the radiation source by the receiving surface. The view factors are available in graphical form and are shown in Exhibit 2. It is necessary to know following parameters to get value of view factor.

- Shape of the opening: round or rectangular. In cases where the opening is not exactly round or rectangular it is necessary to judge based on the shape to select either round or rectangle for getting value of the view factor.
- Diameter of the round opening or width and height of the opening for rectangular

opening

- Thickness of the wall where the opening is located. In cases where the analysis is carried out for round or rectangular containers (ladles, crucibles, stacks etc.), it is necessary to use depth of the opening.

As shown in Exhibit 2, the view factor or % of black body radiation requires calculation of certain ratios that use the information given above.

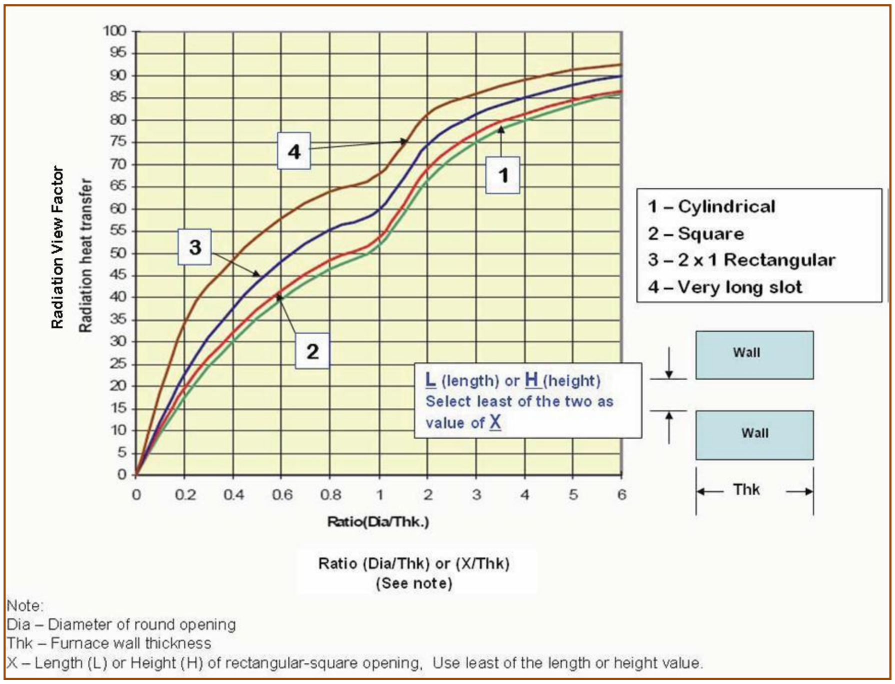

Exhibit 2: Chart used for view factor calculation

T_{source} is the temperature of the radiation source. In this case, it is the interior temperature of the furnace in the area of the opening. It can be measured by using a thermocouple, radiation pyrometer, infrared temperature measuring device. If it is difficult or impractical to measure this temperature, it is possible to use the furnace temperature as indicated by the instrumentation used for the furnace control system.

T_{sink} is the temperature of the receiving surface which, in most cases, would be the ambient temperature.

A is area of the opening calculated based on the dimensions of the opening.

The above information can be used to calculate heat loss expressed as Btu/hour for each opening.

Since this heat loss is a part of the available heat for the furnace, it is necessary to apply available heat factor (known as combustion efficiency) to calculate additional heat input required to compensate for the heat loss.

The term "available heat" is defined as difference in heat input and the heat content of exhaust gases leaving the furnace system. It is usually expressed as percentage (%) and represents the amount of heat remaining in a furnace as a fraction of the heat input to the furnace.

The following symbols are used in the equations below:

H_f = Furnace heat demand (Btu/hr)

H_{av} = Available heat (Btu/hr)

H_{in} = Heat input in the furnace (Btu/hr)

H_{ex} = Heat content of exhaust gases leaving the heating system or furnace (Btu/hr)

Avht(%) = Percent available heat

The total heat input is

So,

Available heat expressed as a percentage is used as a good indication of performance of a heating system and it is given as

So

The term H_f represents sum of heat used for the load and heat losses such as wall heat loss, opening loss, cooling medium loss (if present) etc. Hence, reduction in opening loss would result in reduction in the furnace heat demand or reduction in H_f. Calculation of actual reduction in heat input resulting from opening heat loss reduction requires correction as given below.

For calculating energy savings by eliminating or reducing opening heat losses, two different operating conditions must be considered. One condition (referred to as Current) is an existing furnace condition with including all openings. The other (referred to as Modified) includes measures where openings are eliminated or reduced in size (or some other means). Note that in each case, other furnace heat demands (i.e. heat for the load, wall loss etc.) is considered constant.

$H_{olcurrent}$ = Opening loss with current conditions

$Avht_{current}$ = Available heat at current operating conditions

H_{olmod} = Opening loss with modified condition

$Avht_{mod}$ = Available heat at modified operating conditions

Reduction in wall loss is: $H_{osavings} = H_{olcurrent} - H_{olmod}$

However, reduction in heat input or energy savings (H_{osave}) depends on available heat at each operating condition and savings in energy or reduction in burner heat input can be expressed as

The results are usually expressed in terms of Btu/hour. Annual energy savings ($H_{oannual}$) can be calculated by multiplying the value of H_{osave} by annual operating hours. Note that the opening losses are present at all times as long as the furnace is maintained at operating temperature. In many cases, the furnace is maintained at the operating temperature or slightly lower temperature whether load is processed through the furnace. Hence, the operating hours would represent actual time for which the furnace is maintained "hot".

Avht(%), the available heat expressed as a percentage, depends on the following variables:

- Fuel composition
- Exhaust gas temperature
- Combustion air temperature
- Percent oxygen (dry) in the exhaust gases.

Available heat can be calculated by using combustion calculations for a given fuel. For this opening heat loss calculator tool, these calculations use a typical natural gas composition as found in California and the rest of the USA.

The natural gas composition used for calculations in this tool is given below. Note that the user gives the composition in the column marked "By Volume". If the values in column "By Volume" do not add up to 100% the program will adjust the percentages under column "Adjusted by Volume" to add up to 100% by changing the value of each component % proportionately. In most cases, the total under column "By Volume" is not equal to 100% due to rounding error.

Fuel Gas Analysis (See note below)		
Gas composition	By volume	Adjusted by volume
CH4	94.10%	94.241%
C2H6	2.40%	2.404%
N2 and other inert	1.41%	1.412%
H2	0.03%	0.030%
C3H8	0.49%	0.491%
C4H10 + CnH2n	0.29%	0.290%
H2O	0.00%	0.000%
CO	0.42%	0.421%
CO2	0.71%	0.711%
SO2	0.00%	0.000%
O2	0.00%	0.000%
Total of fuel components	99.85%	100.000%
Difference	0.15%	0.00%
Note: The fuel gas composition is in volume %. The higher hydrocarbons in fuel are treated as same as C4H10 and all other inert gases are treated as N2.		

Exhibit 3: Composition of natural gas used for calculations.

For this calculator, the "higher heating value" or "gross heating value" for the fuel is used. The higher or gross heating value for commonly used natural gas with the composition shown in Exhibit 3 is 1,020 Btu per standard cubic foot (scf). Natural gas heating value varies from as low as 970 Btu/scf to as high as 1,200 Btu/scf. However, in many situations 1,000 Btu/scf is considered a good approximation. Note that minor discrepancies in the heating value have very little effect on the savings achieved with changes (usually reduction) in wall heat losses.

It is recognized that natural gas composition may vary somewhat during the year or from location to location. However, a series of calculations shows that the variation in natural gas composition has very small effect on the available heat as a percentage of the heating value. Therefore available heat changes are within a narrow range and the error for this value is relatively small at within plus or minus 5%. Thus, we advise users of this calculator that the accuracy of its estimates will be in the same order of magnitude (±5%). A separate calculator is available to calculate the exact value of available heat when the fuel composition is known or when the natural gas composition is significantly different from that stated in Exhibit 3.

Further discussion on available heat and the effect of fuel composition is discussed in references 1 and 2.

Annual energy savings ($H_{oannual}$) can be expressed in terms of Btu/year, Therms/year or million Btu/year (MMBtu/year) by using the appropriate equations given below.

The CO_2 savings can be calculated by using the fuel combustion calculations or by using the EPA guidelines for CO_2 generation calculations. Reference 5 gives details of US EPA guidelines.

4. Instruction on use of the calculator

The following list summarizes the user inputs that are required. The user should collect this information before using this calculator tool.

- Company name, plant location and address
- Customer name and contact information
- Heating equipment description (where the energy-saving measure is applied)
- Equipment type (furnace, oven, kiln, heater, boiler)
- Equipment use (e.g., textile drying, aluminum melting, food processing)

Note that some of this information may be optional for the web-based calculators due to users' concerns about privacy.

- Average furnace temperature (°F)
- Ambient temperature (°F)
- Emissivity of the furnace interior
- Rectangular opening width or round opening diameter (ft.).
- Rectangular opening height (ft).
- Opening depth – furnace wall thickness (ft.). .
- Opening area (ft^2)
- View factor – calculated using the chart given as a link to the calculator

- Flue flue gas temperature (°F).
- Oxygen in flue gas (%, dry basis)
- Combustion air temperature (°F)
- Percent opening (%)
- Number of openings of the same size and shape
- Number of operating hours per year (hrs./year)
- Cost of fuel (energy) in terms of $ per MMBtu

The calculator gives following results.

- Radiation heat loss (Btu/hr-ft^2)
- Available heat for the furnace (%)
- Total net heat loss (Btu/hr)
- Heat (energy) loss per year (MMBtu/year)
- Heat (energy) input required for the losses per year (MM Btu/year)
- Heat (energy) savings per year per furnace (MMBtu/year)
- Cost of fuel used for losses ($/year)
- Savings ($/year per furnace)
- CO_2 savings per year (tons/year)

The opening loss calculator requires the following input parameters describing the heating process in order to estimate the savings. Exhibit 4 shows the user information screen and Exhibit 5 shows the calculator screen.

The first section requires information about the user, equipment, and process.

Eliminate or Reduce Opening Heat Loss (Reduce Loss from a Furnace Door Opening)					
1	Company name	ABC Corporation			
2	Plant name or designation	LA Plant			
3	Plant address	12345 Main Street, Gabriel, CA 90878			
4	Contact name	Bob Smith			
5	Contact address	54321 First Street, North Warren, CA 90878			
6	Contact phone number and e-mail	Phone:	916-756-9923	E-mail:	b.smith@abccorp.com
7	Date (format mm/date/year)	May 12, 2010			
Heating equipment description (where the energy saving measure is applied)					
8	Equipment type (e.g. furnace, oven, kiln, heater, boiler)	Oven			
9	Equipment use (e.g., textile drying, aluminum melting)	Metal coating			
10	Other comments if any	The oven is designed to run continuously			

Exhibit 4: Required information for the calculator user

Line 1 – Name of the company.

Line 2 – Name or known designation such as “main plant” or “secondary plant” if applicable.

Line 3 – Plant address.

Line 4 – Contact name for the plant. This is the individual who is main contact and is responsible for collecting and providing the required information.

Line 5 – Address for the contact person.

Line 6 – Contact phone number and e-mail to be used for all future communications.

Line 7 – Date when the calculations are carried out.

Line 8 – Type of heating equipment. This can be an oven, furnace, boiler, heater, etc. This is the heating equipment where data is collected and the given energy saving measure is to be applied.

Line 9 – Process or function for which the heating equipment is used. This can be name of the process such as drying, melting, water heating, etc.

Line 10 – Any additional information that can be useful in application of the results.

The second section of the calculator is used for collecting the necessary data and reporting the estimated savings.

REDUCE LOSS FROM A FURNACE DOOR- OPENING			
		Current	**New**
11	Average furnace temperature (°F)	1,750	1,750
12	Ambient temperature (°F) - Open door	80	80
13	Emissivity for the furnace interior *	0.90	0.90
14	Radiation heat Loss [Btu/(hr.ft^2)]	36,645	36,645
15	Furnace door - opening width (ft.)	10.25	10.25
16	Furnace door - opening height (ft.)	5.00	5.00
17	Surface area (ft^2)	51	51
18	View factor (if applicable)***	0.90	0.90
19	Furnace flue gas temp. (°F)**	1,600	1,600
20	% Oxygen in flue gases from FGA during open door	2.0	2.0
21	Combustion air temp. (°F)	80	80
22	Available heat (%)	54%	54%
23	Door - Opening - open time (minutes) per cycle or charge	15	5
24	No. of cycles or charges per day	12.0	12.0
25	Total net heat loss (MM Btu/day)	5.1	1.7
26	Operating days per year (days/year)	360	360
27	Cost of fuel ($/MM Btu)	$8.00	$8.00
28	Heat loss per year (MM Btu/year)	1,825	608
29	Heat input required for the losses per year (MM Btu/year)	3,377	1,126
30	**Gas Savings per furnace (MM Btu/year)**	**Base**	***2,251***
31	**Cost of fuel used for losses ($/year)**	**$27,017**	**$9,006**
32	**Savings ($/year per furnace)**	**Base**	**$18,012**
33	**CO2 savings (tons/year)**	**Base**	**132**

Exhibit 5: Example of calculator inputs and results

As shown in Exhibit 5, there are two columns for the calculator. The "Current" column represents the conditions or data collected as average values for each of the parameters. Details of the data are given below. Data for the "Modified" conditions represents the values for each of the inputs after the suggested measure (in this case of this calculator, the reduction of openings) is implemented. The calculator cells are color coded. The while color cells are used for data input by the user while the colored (yellow and light blue or green) color cells are protected and give results of the calculations. The user is not allowed change numbers shown in the colored cells.

In most cases, the only input parameter that will change is combustion air temperature. All other values will be same as the "Current" conditions.

Line 11 – <u>Average furnace temperature.</u> Give the furnace temperature (in degrees F.) measured as close to the opening as possible. It can be measured by using a thermocouple, infrared pyrometer or optical pyrometer. If it is not possible to take this measurement, it is possible to use the furnace or furnace zone temperature that is usually measured and displayed on the control panel. The furnace temperature should be taken when the furnace is operating at normal operating conditions. Readings taken at non-average production or operating conditions can give unreliable results.

Line 12 – <u>Ambient temperature</u>. Give ambient temperature at or near location of the opening.

Line 13 – <u>Emissivity of the furnace interior</u>. In most cases, this is approximately 0.9 or higher. This is based on the assumption that the furnace interior is not very shiny and is constructed by using refractory material or oxidized steel for low temperature ovens etc. In rare cases if the interior is very shiny it may be necessary to use lower value and the value should be obtained by contacting the furnace supplier.

Line 14 – <u>Radiation heat loss</u>. This value is calculated using the radiation heat transfer equation discussed earlier. No user input required.

Line 15 – <u>Furnace door opening width</u>. Give opening width of a rectangular opening or diameter if the opening is round. All dimensions are in ft.

Line 16 – <u>Furnace door opening height</u>. Give opening height for a rectangular opening in ft.

Line 17 – <u>Opening area</u>. This is calculated using the dimensions for the opening given above. For rectangular opening it is opening width multiplied by opening height. For round opening it is expressed as area = 0.7854 x (opening diameter)^2. All dimensions are in ft. so the area is expressed as ft^2.

Line 18 – <u>View factor</u>. The view factor depends on geometrical arrangement of surfaces or "available view" of the radiation source by the receiving surface. The view factors are available in graphical form and are shown in Exhibit 2. It is necessary to know following parameters to determine the value of the view factor:

- Shape of the opening: round or rectangular. In cases where the opening is not exactly round or rectangular it is necessary to judgment based on the shape to select either round or rectangle for getting value of the view factor.

- Diameter of the round opening or width and height of the opening for rectangular opening
- Thickness of the wall where the opening is located. In cases where the analysis is carried out for round or rectangular containers (ladles, crucibles, stacks etc.) it is necessary to use depth of the opening.

Line 19 – Furnace flue gas temperature. Give flue or exhaust gas temperature measured as close to the exit of the furnace as possible. The flue gas temperature should be taken when the furnace is operating at normal operating conditions. Readings taken at non-average production or operating conditions can give unreliable results. Give flue or exhaust gas temperature measured as close to the exit of the furnace as possible. The flue gas temperature should be taken when the furnace is operating at normal operating conditions. Readings taken at non-average production or operating conditions can give unreliable results. It is necessary to make sure that the flue gases are NOT mixed with cold air before the temperature is measured. Care should be taken to locate the thermocouple or temperature measurement sensor in the middle of the stack or area from where the flue gases are discharged. Measuring the temperature at the top of the stack or very close to the wall of the discharge duct can give erroneous reading. Note that in almost all cases the flue gas temperature does not change by any significant value with the use of preheated combustion air, since the furnace zone temperatures are controlled to meet the required process conditions.

Line 20 – Percent oxygen (O_2) in flue gases. This is obtained from flue gas analysis using commonly available combustion or flue gas analyzers. These meters give the flue gas analysis on dry basis. The sample for the gas analysis should be taken when the furnace is operating at normal operating conditions. Readings taken at non-average production or operating conditions can give unreliable results. It is necessary to make sure that the flue gases are NOT mixed with cold air before the gas is measured. Care should be taken to locate the sampling probe in the middle of the stack or area from where the flue gases are discharged. Collecting the sample at the top of the stack or very close to the wall of the discharge duct can give erroneous reading. It is also necessary to make sure that there is no air leakage through the sampling port when the sampling probe is inserted in the stack or sampling location.

Line 21 – Combustion air temperature. If possible give measured value of temperature of combustion air entering the burners. In many cases it is not possible to get the exact air temperature at the burner, and it is common to use the temperature of air entering the combustion air blower or the ambient temperature around the air blower. For a case where preheated combustion air is used it is necessary to use combustion air temperature at the burner or at the exit of the air preheating equipment such as a recuperator, regenerator or regenerative burners.

Line 22 – Available heat. This calculated value is based on the information given above and by using the available heat calculator available as one of the calculator tools from this tool set.

Line 23 – Door open time per charge cycle. If the opening is variable opening as in case of a furnace door opening and closing for charging or discharging the load or charge material then this value should be the minutes during the cycle where the door is open.

Line 24 – Number of charges or cycles per day. Give value of number of openings of the same size and shape so that heat loss from all openings can be calculated.

Line 25 – Total net heat loss. This calculated value represents heat loss calculated for one or more of the openings. Note that this heat loss is part of the heat that remains or is available for the furnace.

Line 26 – Number of operating days per year. This represents annual operating hours for which the furnace is maintained at a temperature or remains “hot”.

Line 27 – Cost of fuel. The user gives cost of fuel expressed in terms of $/MM Btu. The cost should include all charges related to use of fuel at “the burner tip”. This value can be obtained directly from monthly or annual gas bills. It is often stated as a line item on the bill. If the bill does not specifically mention the gas cost then it is necessary to calculate average cost of fuel by using values of total fuel cost and annual fuel used.

If necessary contact the fuel (natural gas) supplier or distributor for more information.

Line 28 – Heat loss per year. This is calculated using the values of fuel consumption and the number of operating hours per year given above.

Line 29 – Heat input required for the losses per year. This is a calculated value and represents the heat input required (after allowing for the available heat) in the burners to compensate the heat loss calculated above.

Line 30 – Gas savings per furnace. This is a calculated value. This is the total energy savings in MM Btu that will result from reducing opening losses per year.

Line 31 – Cost of fuel used for losses. Calculated value of fuel cost that is associated with heat input under current and modified conditions.

Line 32 – Savings ($/year per furnace) Calculated savings which is difference in cost of fuel used for losses (line 23 above).

Line 33 – Reduction in CO_2 emissions. These savings are calculated based on annual fuel savings, assuming the fuel used is natural gas. The savings are in Short (US) tons, not in Metric tons.

5. References and resources

1. *North American Combustion Handbook*, Third Edition, 1986. Published by North American Mfg. Company, Cleveland, OH.
2. *Combustion Technology Manual*, Fifth Edition, 1994. Published by Industrial Heating Equipment Association, Cincinnati, OH.
3. *Improving Process Heating System Performance: A Sourcebook for Industry*, U.S. Department of Energy and Industrial Heating Equipment Association. Available online at

   http://www1.eere.energy.gov/industry/bestpractices/pdfs/process_heating_sourcebook2.pdf
4. *Tip sheets and Technical Briefs*, published by The U.S. Department of Energy. Available online at

   http://www1.eere.energy.gov/industry/utilities/steam_tools.html
5. *Unit Conversions, Emission Factors and Other Reference Data*, published by the U.S. EPA, November 2004. Available online at http://www.epa.gov/cpd/pdf/brochure.pdf
6. Training opportunities for process heating technology
   - The U. S. Department of Energy (DOE), Energy Efficiency and Renewable Energy (EERE) Office of Industrial Technologies (ITP) web site. http://www1.eere.energy.gov/industry/
   - Sempra Energy – Southern California Gas Company web site.

     www.socalgas.com
   - California Energy Commission web site.

     http://energy.ca.gov